

REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-02-

0707

IL 0707-0100

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1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE February 22, 2002	3. REPORT TYPE AND DATES COVERED FINAL TECHNICAL REPORT 01/15/98-11/30/01
4. TITLE AND SUBTITLE "VISUAL PROCESSING OF OBJECT VELOCITY AND ACCELERATION"		5. FUNDING NUMBERS G - #F49620-98-1-0197 TA# - 2313/BS
6. AUTHOR(S) Suzanne P. McKee, Ph.D.		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Smith-Kettlewell Eye Research Institute 2318 Fillmore Streets San Francisco, CA 94115		8. PERFORMING ORGANIZATION REPORT NUMBER CFDA #12.800
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NL 801 N Randolph St. Room 732 Arlington, VA 22203-1977		10. SPONSORING / MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by the documentation.		
12 a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.		12 b. DISTRIBUTION CODE

20020401 015

13. ABSTRACT (Maximum 200 words)

This research analyzed the human ability to detect targets moving on predictable paths in the midst of temporally-changing noise. Results from experiments showed that observers easily detected a target (a single bright dot) moving in a consistent direction in the midst of considerable noise, even when this noise consisted of identical features (bright dots) in random motion. Presumably, this ability to detect trajectory motion enables pilots or other military personnel to find aircraft or missiles in the midst of jamming noise. Observers improve their ability to detect motion trajectories with practice, so presumably they learn better strategies with experience. Thus, this task may be useful in training personnel who are required to detect or track targets in noise. Experimental analysis showed that observers use attention to increase the gain of the response to consistent motion, and to reduce the response to the surrounding noise. Fourteen papers were accepted for publication in refereed journals; another paper is in preparation.

14. SUBJECT TERMS

Motion Prediction, Attention, Visual Search

15. NUMBER OF
PAGES

4

16. PRICE CODE

17. SECURITY
CLASSIFICATION
OR REPORT

UNCLASSIFIED

18. SECURITY
CLASSIFICATION
ON THIS PAGE

UNCLASSIFIED

19. SECURITY
CLASSIFICATION
OF ABSTRACT

UNCLASSIFIED

20.
LIMITATION
OF
ABSTRACT

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NSN 7540-01-280-5500 Standard Form 298 (Rev.2-89) Prescribed by ANSI Std. Z39-18 298-102

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

PROGRESS REPORT
January 15, 1998–November 30, 2001

Grant No. F49620-98-1-0197

“VISUAL PROCESSING OF OBJECT VELOCITY AND ACCELERATION”

Principal Investigator: Suzanne P. McKee, Ph.D.

Institution: The Smith-Kettlewell Eye Research Institute
2318 Fillmore Street
San Francisco, CA 94115

TECHNICAL SUMMARY OF WORK ACCOMPLISHED

Predicting the future course of a moving target is obviously invaluable for planning actions, particularly under the demanding conditions of flight. The human visual system takes 100 – 300 msec to process information about moving features, but despite the delay associated with visual processing, observers can readily anticipate the future trajectory of moving features and adjust their motor behavior to compensate for the delay time. Observers make these predictions automatically, without being aware of their “on-line” calculations. Indeed, there is considerable evidence that this predictive capacity is actually a part of early visual processing, and occurs without the symbolic reasoning associated with higher brain functioning. Why is this predictive capacity important? Human observers may be required to detect and respond rapidly to a potentially dangerous moving target that appears suddenly amidst a noisy environment filled with other moving objects.

We designed a special experimental paradigm to study this predictive capability. In a well-controlled experimental setting, we found that observers easily detected a target (a single bright dot) moving in a consistent direction in the midst of considerable noise, even when this noise consisted of identical features (bright dots) in random motion. Presumably, this ability to detect trajectory motion enables pilots or other military personnel to find aircraft or missiles in the midst of jamming noise. We have found that observers improve their ability to detect motion trajectories with practice, so presumably they learn better strategies with experience. Thus, this task may be useful in training personnel who are required to detect or track targets in noise.

Our major objective has been to identify the physiological basis of this trajectory tracking ability, and to model it quantitatively so that similar computational strategies could be utilized in machine vision. In the last two decades, there have been numerous models and algorithms showing how a visual system could predict future motion. Most of these models have proposed a special architecture dedicated to this sole purpose (forward facilitation, self-organizing neural networks, etc.). For human vision, these special formulations are unnecessary. Our latest results show that the human visual system is using a very simple, but general, operation to solve this problem. Basically, any brief consistent motion, i.e., a 100 msec straight motion segment, produces a local neural response that is larger than the responses generated by the surroundings, even in our dynamic noise conditions. The neural response to the brief segment acts a pointer, which directs “attention” to the most likely site of subsequent motion segments. Recent psychophysical and physiological studies of attention have recently shown that it can either increase the gain of neurons at the cued site, or narrow the range and number of detectors that are being monitored (narrow the bandwidth), or some mixture of both processes. In the case of motion trajectories, this ‘cueing’ effect is an automatic process that occurs wherever there are strong local motion signals.

To obtain rigorous psychophysical evidence of gain and bandwidth changes, we measured contrast increments for motion segments at the beginning of the trajectory (first 70 ms) and at the end of the trajectory (last 70 ms). For a trajectory presented in isolation without noise, there was no difference between the contrast increments at the beginning and end of the trajectory. However, when the trajectory was presented in the midst of motion noise, contrast increments were far more detectable at the end of the trajectory than at the beginning. Using a signal detection model, Dr. Preeti Verghese showed quantitatively that the major effect of the early cueing was to reduce uncertainty; the observer was narrowing the type and number of detectors being monitored to be consistent with the predicted future direction. In neural terms, the motion detector which is driven optimally by the early segment of the trajectory probably suppresses detectors that are tuned to different directions and locations, thereby narrowing the effective bandwidth of the detector array that responds to later segments of the trajectory. We also showed that non-motion cues could enhance trajectory detection. For example, we flashed four static dots lying in a row on the path of a subsequently presented brief (100 ms) trajectory) in motion noise. The brief trajectory was much more easily detected with the static cue than without it. However, a single bright dot flashed 50ms before the trajectory had little effect.

Burgi, Yuille and Grzywacz showed that a computer algorithm could also find dot moving on a straight trajectory amidst motion noise. Basically, their algorithm assessed the average statistics of the noise, and then searched for moving points that were outliers relative to the noise distribution. Because our noise dots were moving in Brownian motion (randomly chosen direction on each frame), the probability that any given noise dot would move in exactly the same direction for three sequential frames was very small. Therefore, in three frames, the algorithm could find the trajectory dot, because it moved in the same direction on all three frames. Of course, the computer was given the data about the locations and directions of every dot in the display. There was no requirement that the computer measure the pixels to obtain this information. But the human observer has this limitation. Undoubtedly the human visual system measures direction and location, using motion detectors that coarsely sample space and time. To make precise measurements of the directions of the noise dots, these neural motion detectors must integrate the signal for 70 –100 msec (5 –8 frames). It is very likely that any real detector, whether composed of neurons or silicon, would need some time to assess the statistical distribution of the noise directions. But, after the motion measurements are made, the human visual system uses an outlier approach that is similar to the computational algorithm. It estimates the average response level generated by whole stimulus

display, and then identifies local deviations from this response level. These local deviations alert the visual system to points of interest. The largest local deviation is caused by the first 70 – 100 msec of the trajectory dot motion. In regions near the large directionally-selective response generated by the trajectory, the motion system increases the gain of motion detectors tuned to similar directions and suppresses signals from motion detectors at other locations. These physiological operations are used by the human visual system to 'predict' the likely direction of motion by enhancing some responses and diminishing others – a kind of physiological Kalman filter.

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Personnel Supported and/or Associated with Project:

Suzanne P. McKee, Ph.D. Principal Investigator
Preeti Verghese, Ph.D., Co-investigator
Norberto M Grzywacz, Ph.D. Co-investigator
Alan L. Yuille, Ph.D., Co-investigator
Douglas G. Taylor, B.S., Programmer-Engineer